

Memorandum

Date: June 28, 2016

To: Ms. Lynn Sadler
Deputy Director
Department of Parks and Recreation

From: Sandra Morey, Deputy Director 
Ecosystem Conservation Division

Subject: Risk Assessment for Eurasian watermilfoil (*Myriophyllum spicatum*)

Per the August 26, 2014, letter requesting risk assessments for five species of aquatic plants identified by the California Department of Parks and Recreation as potentially invasive, please find enclosed the California Department of Fish and Wildlife's (CDFW) risk assessment findings and determination regarding Eurasian watermilfoil (*Myriophyllum spicatum*). Per Harbors and Navigation Code, section 64.5, CDFW included in their assessment:

- Whether Eurasian watermilfoil may obstruct navigation and recreational uses of waterways;
- Whether Eurasian watermilfoil may cause environmental damage, including threats to the health and stability of fisheries, impairment to birds' access to waterways and nesting, roosting, and foraging areas, deterioration of water quality resulting from plant decay, and harm to native plants;
- Whether Eurasian watermilfoil may cause harm to the state's economy, infrastructure, or other manmade facilities such as state water storage facilities and pumping operations, by increasing flood risk, threatening water supplies by blocking pumps, canals, and dams necessitating early control efforts; and
- Whether Eurasian watermilfoil causes or is likely to cause any other harm to California's environment, economy, or human health or safety.

To ensure thorough consideration of the species' ecological characteristics and the specified impacts and threats, CDFW employed the U.S. Aquatic Weed Risk Assessment tool. As specified in sec. 64.5, CDFW consulted with the Department of Food and Agriculture, the Department of Water Resources, the State Water Resources Control Board, the Department of Pesticide Regulation, and the Office of Environmental Health Hazard Assessment, to develop the risk assessment findings and determination.

As fully detailed within the enclosed risk assessment, CDFW concludes that Eurasian watermilfoil should be considered an invasive aquatic plant that causes or is likely to cause economic or environmental harm or harm to human health in California.

Ms. Lynn Sadler, Deputy Director
Department of Parks and Recreation
June 28, 2016
Page 2 of 4

CDFW staff have completed draft risk assessments for two other species requested, water primrose (*Ludwigia hexapetala*) and coontail (*Ceratophyllum demersum*), which are currently undergoing internal review. CDFW staff have begun assessment of Carolina fanwort (*Cabomba caroliniana*), the fifth of five requested assessments.

If you have any questions regarding this risk assessment, or the others in process, please contact Ms. Martha Volkoff, Habitat Conservation Planning Branch, Invasive Species Program, at (916) 651-8658 or by email at Martha.Volkoff@wildlife.ca.gov.

Enclosure

cc: **California Department of Parks and Recreation**
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Aquatic Plant Risk Assessment

Eurasian watermilfoil, *Myriophyllum spicatum* L.

May 23, 2016

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INTRODUCTION

The California State Parks' Division of Boating and Waterways (DBW) is the lead agency of the state for the purpose of cooperating with other state, local, and federal agencies in identifying, detecting, controlling, and administering programs to manage, control, and when feasible, eradicate invasive aquatic plants in the Sacramento-San Joaquin Delta, its tributaries, and the Suisun Marsh. Harbors and Navigation Code §64.5 defines an "invasive aquatic plant" as an aquatic plant or algae species, including its seeds, fragments, and other biological materials capable of propagating that species, whose proliferation or dominant colonization of an area causes or is likely to cause economic or environmental harm or harm to human health. Per §64.5, for aquatic plant species that DBW believes may be invasive and desires to manage, control, or eradicate, DBW shall request that the California Department of Fish and Wildlife (CDFW) conduct a risk assessment to determine if the species causes or is likely to cause economic harm or environmental harm or harm to human health. The risk assessment shall be documented in a way that clearly describes the severity and types of impacts caused or likely to be caused by a plant species determined to be an invasive aquatic plant. Within 60 days after completing the risk assessment CDFW shall report its findings to DBW.

DETERMINATION

Per DBW's August 26, 2014 request, CDFW evaluated whether Eurasian watermilfoil, *Myriophyllum spicatum* (EWM), should be considered an invasive aquatic plant in California. To make the determination, CDFW selected a quantitative assessment tool that evaluated aspects of the species' ecology, reproductive potential, dispersal mechanisms, competitive ability, actual and potential impacts (including impacts to navigation and recreation, the environment, economy, and human health as specified in Harbors and Navigation Code §64.5), and resistance to management. Based on this evaluation and the findings contained herein, CDFW, in consultation and concurrence with California Department of Water Resources (DWR), State Water Resources Control Board (SWRCB), Department of Food and Agriculture (CDFA), Department of Pesticide Regulation (DPR), and Office of Environmental Health Hazard Assessment (OEHHA), determines that Eurasian watermilfoil is an invasive aquatic plant that causes, or is likely to cause, economic or environmental harm, or harm to human health in California.

CURRENT DISTRIBUTION

EWM, native to Europe, Asia, and northern Africa, has been introduced to and is considered invasive in temperate areas of North America (United States and Canada), Australia, and southern Africa (CABI 2011; Tomaino 2004). Though there is disagreement over the timing and means of introduction (possibly by 1881; ballast water vs. aquaria), EWM had been introduced to the northeastern U.S. and reached nuisance levels in Chesapeake Bay by the 1940s (Aiken et al. 1979; Smith and Barko 1990). By 1950, EWM had reached central California, and by 1985 had spread throughout much of the U.S. and southern Canada (Reed 1977; Aiken et al. 1979; Couch and Nelson 1985). EWM is now present throughout much of California, and has been documented in each of the geographic provinces classified by the State Wildlife Action Plan (CDFW 2015): Central Valley and Sierra Nevada, Cascades and Modoc Plateau, North Coast and Klamath, throughout the Bay-Delta and Central Coast, including the East, West, and South (San Francisco) Bay, South Coast, and Deserts (Calflora 2015).

Though the California Department of Food and Agriculture has not listed EWM as a noxious weed, it is categorized as having a “high” (severe) level of negative ecological impacts in California (Cal-IPC 2006) and is identified as invasive or regulated as noxious, restricted, or prohibited in the states of ME, NH, VT, MA, CT, NC, SC, GA, FL, AL, TN, IL, WI, SD, TX, NM, CO, MT, ID, NV, WA, and OR (CISEH 2013; USDA 2014).

RISK ASSESSMENT

EWM was assessed using the U.S. Aquatic Weed Risk Assessment (USAqWRA) tool, which was modified for the U.S. by Gordon et al. (2012) from the New Zealand Aquatic WRA model (Champion and Clayton 2001). The USAqWRA functions as the aquatic alternative to the Australian WRA, which is widely accepted and applied, but inaccurately classifies nearly all aquatic species as invasive, thus requiring modification for the accurate assessment of aquatic plants (Gordon and Gantz 2011). The USAqWRA has been tested for accuracy and validated under the environmental conditions of the U.S. and is the only assessment tool developed for the U.S. that maximizes accuracy for aquatic plants and incorporates all of the factors outlined in Harbors and Navigation Code §64.5.

The USAqWRA defines non-invaders as having no evidence of establishment outside of cultivation (in non-native ranges). Minor invaders are defined as species that have established in non-native ranges, but with no described ecological impacts. Major invaders are defined as having established in non-native ranges, and having documented, negative ecological impacts. Species are categorized using a scoring system of <31 (non-invaders), 31 – 39 (evaluate further), and >39 (major invaders). Gordon et al. (2012) determined that using the threshold score of 39 to distinguish major invaders from both minor and non-invaders maximized overall accuracy of the assessment tool at 91%.

CDFW conducted a thorough search of peer-reviewed journals and government publications to accurately complete the assessment. The resulting evaluation of EWM invasiveness (Appendix A) produced a score of 76, predicting EWM to be a “major invader” of the Sacramento-San Joaquin Delta. The findings using the USAqWRA model are summarized below, along with additional findings relevant to assessing potential impacts.

ECOLOGY

EWM is a submersed, perennial macrophyte that exhibits an annual growth pattern. In colder climates, established EWM plants die back and overwinter as root crowns, and new shoots are initiated from crowns when water temperatures reach approximately 15°C (59°F) (Aiken et al. 1979). Rates of shoot elongation are dependent upon light availability, but once near the surface, stems branch extensively and form a light-intercepting canopy (Grace and Wetzel 1978; Smith and Barko 1990). Sloughing of the lower stems and leaves is common, and creates a constant source of nutrient loading in the water column (Smith and Adams 1986). However, there is little winter dieback in regions where water temperatures do not drop below 10°C (50°F) (Aiken et al. 1979). Populations in western

Washington, California, and Tennessee are reported to overwinter with large amounts of photosynthetic biomass (Stanley et al. 1976; Bossard et al. 2000; WADOE n.d.).

EWM is common in a wide variety of habitats, including rivers, streams, irrigation canals, drains, lakes, and ponds (ISSG 2006). It can be found growing in depths of 1 – 10 m, depending upon water clarity and light penetration, but is most commonly found at 1 – 4 m (Aiken et al. 1979; Nichols and Shaw 1986). EWM is tolerant of oligotrophic waters, but well suited for eutrophic systems and is considered an indicator species for eutrophication (Nichols and Shaw 1986). EWM is tolerant of sandy to acid-peat substrates, but grows best in fertile, fine sediments, where anchoring is not inhibited by coarse substrates (Aiken et al. 1979; Nichols and Shaw 1986; Bossard et al. 2000). In brackish waters, EWM grows uninhibited in salinities up to 10 ppt; growth is reduced above 10 ppt, but survives in salinities to 20 ppt (Springer et al. 1961; Martin and Valentine 2014). EWM tolerates acidic to basic waters, and has been documented in waters ranging from pH 5.4 – 11 (Aiken et al. 1979).

REPRODUCTIVE POTENTIAL

EWM reproduces sexually and vegetatively, through both allo- and auto- stem fragmentation and stoloniferous growth (Smith and Barko 1990). Root crown budding may begin as early as January, and plants are well established by April (Aiken et al. 1979). As stems reach the surface, they branch profusely and flower on terminal spikes that protrude up to 20 cm above the water surface. Flowering occurs from June to September, and each wind-pollinated spike can produce up to 112 seeds (Aiken et al. 1979; Madsen and Boylen 1988; DiTomaso and Healy 2003). Mature seeds drop into the water, may float for several hours, and typically exhibit prolonged dormancy (7 years; Aiken et al. 1979). However, though seed set can near 4 million per hectare, *in situ* germination is erratic and the noticeable absence of germination and seedlings in the field is often cited as indicating the relative unimportance of sexual reproduction in dispersal and propagation (Aiken et al. 1979). Flowering tends to coincide with peak biomass, after which autofragmentation is typically induced; 10 – 20 cm shoot apices abscise from the parent plant, with fragment roots reportedly developing from nodes prior to abscission (Grace and Wetzel 1978; Aiken et al. 1979). Allofragments, those produced by physical damage, are frequently caused by wave action, boats, human activities, or animals, and develop roots after separation. In warmer climates, where flowering occurs early in the season, EWM may exhibit a second peak in biomass and subsequent period of flowering and fragmentation (Adams and McCracken 1974).

DISPERSAL MECHANISMS

EWM expansion and dispersal occurs primarily vegetatively, through stolons and plant fragments, given that germination of EWM seeds in the field appears to be rare (Madsen et al. 1988; Madsen and Smith 1997). EWM is able to rapidly expand within a waterbody via stoloniferous growth from root crowns (expansion of a few meters) and colonization of new areas, which is primarily by establishment of plant fragments (Aiken et al. 1979; Smith and Barko 1990; Madsen and Smith 1997; Bossard et al. 2000). Dispersal of plant fragments within a waterbody may occur via transport by watercraft, recreational gear, equipment, aquatic animals, or water currents. Regional (inter-lake) dispersal of plant fragments is largely due to transport on watercraft and trailers, though EWM fragments are also easily transported on recreational gear, by water currents (e.g. rivers, canals), or on waterfowl plumage (Bossard et al. 2000; Rothlisberger et al. 2010). The aquarium trade previously played a substantial role in expanding the distribution of EWM in the U.S., and dumping excess or unwanted EWM from aquatic gardens and aquaria has been documented as a common means of spread (Bossard et al. 2000).

COMPETITIVE ABILITY

EWM fragments rapidly colonize previously unvegetated areas or newly created habitat following sediment deposition, water level changes, or the reduction or removal of other submersed macrophyte populations (Smith and Barko 1990). EWM readily invades disturbed areas and once established is able to displace and/or suppress other native and invasive submersed macrophyte populations (Madsen et al. 1991; Boylen et al. 1999). However, EWM is

reported to have difficulty colonizing within established vegetation (Smith and Barko 1990; Illinois EPA 1996; Michigan Sea Grant 2012; DBW, personal communication).

REALIZED AND POTENTIAL IMPACTS

Obstruction of Navigation and Recreation

At and below the water surface, EWM forms expansive canopies of dense, tangled growth that can be thick enough to support the weight of frogs and wading birds. The dense growth impedes waterway navigability, recreational angling, and water-based recreational activities (Newroth 1985). The long, branched stems of EWM tangle boat propellers and fishing gear and may restrict access to boat ramps and docks. Recreational angling quality is also impacted as EWM can cause declines in community diversity and sport fish population abundances and/or biomass by reducing predation success (Eiswerth et al. 2000).

Mats of EWM inhibit swimming and shoreline recreation by tangling swimmers, restricting access, and fouling shores with decaying mats of EWM. During 2015, EWM became a nuisance weed at several State Water Project facilities. EWM was present at very high density in Silverwood Lake (San Bernardino Co.), and negatively affected shoreline recreation (swimming access was difficult and potentially unsafe) and boating. The water level at Silverwood Lake dropped considerably over the summer and fall, exposing EWM that decomposed on the shore and caused unpleasant conditions. O'Neill Forebay (Merced Co.) also contained a mix of aquatic weeds, which included EWM (though it was not the dominant species), that impeded boating and fishing. During 2014, EWM was found at high density in Thermalito Forebay (Butte Co.), where it impeded recreation (B. Sakata, DWR, personal communication).

Environmental Effects

Water quality – Dense stands of EWM negatively impact water quality through a variety of mechanisms. EWM increases nutrient loadings through continual sloughing of lower leaves, reduces dissolved oxygen levels through decomposition, increases sedimentation rates, and can increase lake temperature profiles by up to 10°C (50°F) in shallow waters (Dale and Gillespie 1977; Bates et al. 1985; Nichols and Shaw 1986; Madsen 1997).

Native plants – Through shading and competition for resources, EWM reduces both richness and cover of native plant species across submersed, emergent, and floating growth habits (Madsen et al. 1991; Boylen et al. 1999). Boylen et al. (1999) documented EWM suppression and displacement of plant species across other growth forms as well (i.e., emergent, floating), including species native to California, such as yellow pondlily (*Nuphar polysepala* Engelm.), common bladderwort (*Utricularia macrorhiza* Leconte), and longbeak buttercup (*Ranunculus longirostris* Godr.). Further, Boylen et al. (1999) documented suppression or displacement of species listed as rare in California, including water star-grass (*Heteranthera dubia* (Jacq.) MacM.), white-stemmed pondweed (*Potamogeton gramineus* L., *P. praelongus* Wulfen), Robbins' pondweed (*P. robbinsii* Oakes), and eel-grass pondweed (*P. zosteriformis* Fern.), which are on the California Native Plant Society Inventory of Rare and Endangered Plants lists 2B.2, 2B.3, 2B.3, and 2B.2, respectively (CNPS 2015).

Birds and waterfowl – EWM is a low nutritive-value food species for waterfowl and, through competition, reduces abundance of desirable, more nutritional waterfowl plant foods (Elser 1969; Aiken et al. 1979). Due to its submersed nature, EWM is not recognized for restricting birds' access to roosting, foraging, or nesting habitats and in some ecosystems is recognized for slowing waters and facilitating waterfowl usage.

Health and stability of fisheries – In stagnant waters where growth is extensive, compounds found in EWM cause mortality of 1st and 4th instar larvae of chironomid midges (Dhillon et al. 1982), which are an important food source for trout and a major dietary component of juvenile Chinook salmon in the Sacramento River, its

tributaries, and the Delta (Merz and Vanicek 1996; Simenstad et al. 2000; Merz 2001; Sommer et al. 2001; Limm and Marchetti 2003). Extensive EWM infestations have impacted fisheries by harboring forage fishes and reducing predation success, resulting in overabundant, stunted forage fish populations and reduced production of predatory sport fish (Nichols and Shaw 1986; Smith and Barko 1990). However, in California excessive growth of submersed aquatic vegetation has been observed to benefit predator success by providing ambush cover, slowing flow velocities, and increasing sedimentation rates, which results in improved water clarity and visibility for ambush predators.

DWR is required to reduce predation of endangered fish species in Clifton Court Forebay (CCF) in the Delta, and one measure identified to help achieve this is reducing the amount of aquatic weeds to remove hiding places for predators. Aquatic weed control in CCF is difficult due to special restrictions on herbicide applications when endangered fish may be present. EWM is not currently dominant in CCF, but if it became established, its control would potentially be more difficult due to these restrictions, and therefore make it more difficult for DWR to decrease predation of endangered fish in CCF (B. Sakata, DWR, personal communication). Of additional concern for California's native salmon and trout populations, excessive growth of EWM has reduced spawning success of salmonids by covering spawning gravels (Newroth 1985).

Economic, Infrastructure, or Man-made Facilities

EWM infestations negatively impact the state's economy, infrastructure, and facilities. Along with infesting municipal water supplies, EWM clogs dam trash racks, municipal intakes, irrigation pumps, and industrial and hydroelectric power plant intakes (Smith et al. 1967; Aiken et al. 1979; Bates et al. 1985; Howard-Williams 1993; Eiswerth et al. 2000), increasing maintenance costs to water and electric providers, which are subsequently passed along to consumers. Stands of EWM also have the ability to increase the risk of flooding by restricting the operation of flow metering devices in flood control channels (Dale and Gillespie 1977).

Aquatic weeds are a recurring problem at State Water Project (SWP) facilities: trash racks at pumping plants become clogged, causing shutdowns; weeds often have to be manually removed by staff, leading to large overtime expenses; and the use of herbicides and weed harvesters to control weeds in the SWP also represent an additional expense. EWM is currently more of a recreational nuisance than an operational nuisance in the SWP, as the areas it currently dominates are mainly used for recreation. However, it is present throughout the SWP and common in areas where other aquatic weeds are dominant and causing operational problems. Should EWM become the dominant species in the SWP operational areas, it would likely cause further operational issues (B. Sakata, DWR, personal communication).

The aesthetic and physical impacts of EWM invasions further impact the economy by reducing real estate values and recreational-use revenues. In northern Wisconsin, waterfront properties experienced an 8% decrease in value following EWM invasion (Horsch and Lewis 2009). Waterfront properties on EWM-infested lakes in King County, Washington, averaged a 19% reduction in property values (from 1995 – 2006) compared to those on non-infested lakes, with further implications to local property tax revenue (Olden and Tamayo 2014). In an effort to quantify the economic damages of EWM infestations to western Nevada and northeastern California, Eiswerth et al. (2000) conservatively estimated that a 1% decline in recreation values at a small subset of recreational areas within the Truckee River watershed would equate to a loss in revenue to the region of at least \$500,000 per year.

Human Health

Dense EWM growth retards water flow and creates stagnant conditions, ideal habitat for parasites that cause swimmer's itch (*Cercarial dermatitis* and *Schistosoma dermatitis*) and mosquito reproduction, thus potentially increasing the prevalence of insect-borne diseases such as West Nile virus (Eiswerth et al. 2000; CAST 2014).

Pyramid Lake (Los Angeles Co.), where aquatic weeds are commonly a nuisance in swimming areas and boat-in

day use areas, had an outbreak of swimmer's itch during August 2015; unconfirmed cases of swimmer's itch were also report in Silverwood Lake in June 2015 (B. Sakata, DWR, personal communication).

Dense growth of EWM can cause increased water levels and risk of flooding by reducing water flow or interfering with flow-metering devices in flood control channels. A less conspicuous but still prevalent threat to human health and safety is the role aquatic plants play in entangling swimmers and causing or contributing to drownings. CAST (2014) conducted a cursory internet review for drownings related to entanglement in aquatic weed infestations; their search revealed 12 drowning incidents in EWM- (or hydrilla-, *Hydrilla verticillata*) infested waters from 1990 – 2007 within 5 U.S. states, including California.

RESISTANCE TO MANAGEMENT

A variety of control methods exist for EWM, including hand removal, mechanical harvesting, diver-assisted suction dredging, benthic barriers, biological control agents, and herbicides (DiTomaso et al. 2013). Herbicide applications are the most widely applied and typically the most effective method for controlling EWM. Common herbicides used in EWM treatment include 2,4-D, diquat, penoxsulam, imazamox, and fluridone, all of which are registered with the U.S. Environmental Protection Agency and the California Department of Pesticide Regulation, and have been applied to other species in the Delta under DBW's existing aquatic weed control programs.

The aforementioned active ingredients are currently allowed for use under the Statewide General National Pollutant Discharge Elimination System (NPDES) Permit for Residual Aquatic Pesticide Discharges to Waters of the United States from Algae and Aquatic Weed Control Applications, Water Quality Order 2013-0002-DWQ. However, if additional aquatic pesticide active ingredients approved by DPR are proposed to be used for EWM control other than 2,4-D, acrolein, calcium hypochlorite, copper, diquat, endothall, fluridone, glyphosate, imazamox, imazapyr, penoxsulam, sodium carbonate peroxyhydrate, sodium hypochlorite and triclopyr-based algaecides and aquatic herbicides, and adjuvants containing ingredients represented by the surrogate nonylphenol, the State Water Resources Control Board (SWRCB) can amend the above referenced permit to add the DPR-approved aquatic pesticide(s). The amendment process typically requires around 4 months to process and is initiated by written request to the SWRCB-Division of Water Quality (R. Norman, SWRCB, personal communication).

Assessing EWM infestations may be more difficult due to its submersed growth habit and similarities in appearance with native and non-native congeners, northern watermilfoil (*M. sibiricum*) and parrotfeather (*M. aquaticum*), respectively, and native coontail (*Ceratophyllum demersum*). While the submersed nature of growth does not necessarily create a challenge for management implementation, interspersed EWM with other species not yet authorized for treatment and existing regulations in the Delta pose some challenges to implementation of management efforts.

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APPENDIX A: Risk Assessment of Eurasian watermilfoil, *Myriophyllum spicatum*

Species: <i>Myriophyllum spicatum</i>; Eurasian watermilfoil					
	Question - USAqWRA	Score and guidance – USAqWRA	Score	Justification	Reference
1.1	Temperature tolerance	(0-3) Score 3 if maintains photosynthetic tissue and summer growth form throughout winter, 2 if dies back to tuber/bulb/rhizome (or similar structure) during winter, 1 if adult plants completely die but viable seeds remain. Use a climate matching tool if direct evidence is not available. Default = 1 for annual species.	3	May die back and overwinter as root crowns, though some populations (e.g. in western Washington) overwinter with a large amount of photosynthetic biomass. In CA, stolons and lower stems also persist over winter.	Stanley et al. 1976; Bossard et al. 2000
1.2	Range of habitat	(1-3) Score 3 if able to grow from water to dry land, 2 if water to wetland, or from shallow to deep (>5 m) water, 1 narrow range.	2	Growth in depths ranging from 1.0 - 10 m; poor growth in < 1.0 m.	Parkinson 2011; Aiken et al. 1979; Smith and Barko 1990
1.3	Water/ substrate type tolerance	(1-2) Score 2 if tolerant of sandy to muddy (or peaty) substrate, or oligotrophic to eutrophic waters, 1 if restricted by either. Default = 1 if no information is available.	2	Tolerant of eutrophic water; may be impeded by sandy or very fine, organic substrates.	Bossard et al. 2000; Nichols and Shaw 1986; Aiken et al. 1979
1.4	Water clarity tolerance	(0-1) Score 1 if unaffected by water clarity (i.e. floating or emergent, or submergents tolerant of very low light levels, such as <i>Myriophyllum spicatum</i> and <i>Hydrilla verticillata</i>), 0 if affected by water clarity.	1	Is poorly tolerant of shade, thus canopy formation is likely a response to low light levels, which negates effects of water clarity.	Madsen et al. 1991
1.5	Salinity tolerance	(0-1) Score 1 if species can tolerate saline conditions, 0 if not. Habitat information can be used to determine a score of 0 if species is only found to occur in freshwater habitats.	1	Reduced growth beyond 10 ppt, but survives at 20. Flowering and fragment root production are reduced at elevated salinities.	Springer et al. 1961; Martin and Valentine 2014
1.6	pH tolerance	(0-1) Score 1 if tolerant of both acidic and basic pH or no information is available, 0 if restricted to neutral, basic, or acidic pH.	1	Tolerant of pH from 5.4 - 11	Aiken et al. 1979
1.7	Water level fluctuation - Tolerates periodic flooding/drying	(0-3) Score 3 for species which have evidence of tolerating periodic flooding/drying with a specified time period longer than 1 month (e.g., "months"; "X months", "winter flooding"), 2 for evidence of tolerance of flooding/drying over a period of days/a couple of weeks, 1 for species that die back during periods of flooding/drying, and 0 for species that do not tolerate flooding/drying.	2	Complete dewatering for 21 consecutive days resulted in plant mortality.	Smith 1963

Species: <i>Myriophyllum spicatum</i>; Eurasian watermilfoil					
	Question - USAqWRA	Score and guidance – USAqWRA	Score	Justification	Reference
2.1	Lentic - rivers, streams, drains, or other flowing waters, including their margins	(0-3) Score 3 if major weed (reaches high density and dominates plant community), 2 if minor weed (common, but rarely or never dominant), 1 if present but not weedy, 0 if absent.	3	Creates dense infestations and large mats in low energy areas of rivers and streams	CABI 2011
2.2	Ponds, lakes and other standing waters, including their margins	(0-3) Score 3 if major weed (reaches high density and dominates plant community), 2 if minor weed (common, but rarely or never dominant), 1 if present but not weedy, 0 if absent.	3	Creates dense infestations and large mats in lakes, ponds, and shallow reservoirs	CABI 2011
2.3	Swamp, marsh, bog, or other wet areas not covered by 2.1 or 2.2	(0-3) Score 3 if major weed (reaches high density and dominates plant community), 2 if minor weed, 1 if present but not weedy, 0 if absent.	3	Creates dense infestations and large mats in disturbed areas, wetlands, protected tidal creeks and bays.	ISSG 2006; Galatowitsch et al. 1999; Trebitz and Taylor 2007
2.4	Establishment – into existing vegetation	(-5, -3, 0) Score 0 if able to invade unmodified vegetation, -3 if the species can only colonize certain types of vegetation (e.g., turf-forming shoreline vegetation), -5 if there is no evidence that the species can move into intact vegetation. Default = 0 if there is evidence of establishment, but no specific information about level of invasion into existing vegetation and/or type of vegetation being invaded. Default = -3 for species that have not naturalized outside of their native range.	-3	Difficulty establishing within healthy, established populations.	IL EPA 1996, Michigan Sea Grant 2012, DBW pers. comm.
2.5	Establishment – into disturbed vegetation	(0, 1, 5) Score 5 if able to aggressively colonize following vegetation clearance, newly constructed waterbodies or nutrient enrichment, 1 if the species grows in disturbed areas, but there is no other information, 0 if there is no evidence of establishment in disturbed areas. Information from either the native or introduced range may be used to answer this question. Default = 1 for no information.	5	Rapidly colonizes disturbed areas or new habitat following sediment deposition, water level changes, or vegetation decline or removal.	Smith & Barko 1990
3.1	Competition – between growth form	(0, 1, 2) Score 2 if species forms dense stands that are documented to displace other growth forms (submersed, floating, emergent), 1 if some suppression, 0 if no displacement. Default = 0 if species has been in the trade globally for >30 years and there is no information about the species displacing other growth forms.	2	Displaces submersed, emergent, and floating species.	Boylen et al. 1999

Species: *Myriophyllum spicatum*; Eurasian watermilfoil

	Question - USAqWRA	Score and guidance – USAqWRA	Score	Justification	Reference
4.1	Dispersal outside catchment by natural agents (e.g. birds, wind)	(0, 1, 3, 5) Score 5 if species (including seeds, rhizomes, fragments etc.) well adapted, and likely to be frequently dispersed, by natural agents, 3 if transport by natural agents is possible but uncommon, 1 if propagule could be spread in bird crop, 0 if no, or extremely low, likelihood of dispersal by natural agents (e.g., <i>Hydrilla</i> is scored 1 because its turions can survive passage through duck guts, an agent of dispersal, but this is believed to happen rarely).	5	Fragments disperse by wind, water flow between bodies, and waterfowl.	DiTomaso and Healy 2003
4.2	Dispersal outside catchment by accidental human activity	(1, 2, 3) Score 3 if major pathway, seeds/fragments adapted for easy transportation (e.g., via boat/trailer, fishing gear), 2 if the species is a floating plant or a macrophyte, but no explicit mention of high spread in the literature, 1 not mentioned, not likely to be spread by human activity based on growth form and life history. Default = 1 if no information is available.	3	Watercraft and equipment transport is likely the largest role in spread to new locations.	Johnstone et al. 1985; Rothlisberger et al. 2010
4.3	Dispersal outside catchment by deliberate introduction	(0-1) Score 1 if species is desirable to humans (e.g., or used for medicinal, food, ornamental, restoration, etc. purposes in the U.S. or elsewhere). If species is not used or no information exists, score should be 0.	0	Previously common in the aquarium trade, but no longer a substantial issue.	Hoffman and Kearns 1997
4.4	Effective spread within waterbody/catchment	(0-1) Score 1 for extensive spread within a waterbody or among waterbodies, 0 for no spread. Occurrence along streams or riverbanks or in rivers can be used as evidence, as well as evidence of water dispersal. Do not answer if no information is available.	1	Stem fragments spread easily via water currents.	Kimbel 1982; Nichols and Shaw 1986; Madsen et al. 1988; Madsen and Smith 1997
5.1	Generation time (time between germination of an individual and the production of living offspring, not seeds or other dormant structures)	(1, 2, 3) Score 3 if rapid (reproduction in first year and >1 generation/year), 2 if annual or produces one generation every year including the first year, 1 if not reproductively mature in the first year. Default = 1 if no information is available.	3	Viable fragments are produced throughout the growing season, sprouting roots sometimes before fissure. Flowering and fragmentation may occur twice within a growing season.	Smith and Barko 1990; Aiken et al. 1979; Adams and McCracken 1974; Kimbel 1982
6.1	Seeding ability - Quantity	(0-3) Score 3 if >1000 seeds/plant/year, 2 100-1000, 1 <100 and/or evidence that seed are produced (in native or introduced range), 0 if seed not produced.	2	Approximately 112 seeds per spike.	Madsen and Boylen 1988; Aiken et al. 1979

Species: <i>Myriophyllum spicatum</i> ; Eurasian watermilfoil					
	Question - USAqWRA	Score and guidance – USAqWRA	Score	Justification	Reference
6.2	Seeding ability - Viability/ persistence	(0-2) Score 2 if highly viable for >3 years, 1 low viability or evidence of seed production with no information on viability, 0 no viable seeds.	1	Seeds may remain dormant for >7 years, but viability and germination is low.	Aiken et al. 1979
7.1	Vegetative reproduction	(0, 1, 3, 5) Score 5 for naturally fragmenting from rhizomes, stolons, or other vegetative growth into tissue capable of producing new colonies (e.g., <i>Egeria densa</i>), 3 if produces rhizomes/stolons, but there is no other information about the formation of new colonies elsewhere, 1 for clump-forming by vegetative spread, 0 for no vegetative spread.	5	Exhibits extensive allo- and auto-fragmentation.	Aiken et al. 1979
8.1	Physical-water use, recreation	(0-2) Score 2 for major nuisance, 1 for minor nuisance. Default = 0 if the species has not naturalized outside of its native range.	2	Major nuisance of waterways, lakes, shorelines, marinas, etc.	Eiswerth et al. 2000
8.2	Physical – access	(0-2) Score 2 for major nuisance, 1 for minor nuisance. Default = 0 if the species has not naturalized outside of its native range.	2	Infestations in and around marinas, docks, and ramps restrict boating access.	Eiswerth et al. 2000
8.3	Physical - water flow, power generation	(0-2) Score 2 for major nuisance, 1 for minor nuisance. Default = 0 if the species has not naturalized outside of its native range.	2	Clogs industrial, power plant, and municipal supply water intakes, infests municipal water sources.	Eiswerth et al. 2000; Bates et al. 1985
8.4	Physical - irrigation, flood control	(0-2) Score 2 for major nuisance, 1 for minor nuisance. Default = 0 if the species has not naturalized outside of its native range.	2	Clogs drainage ditches, irrigation canals, farm ponds, irrigation equipment.	Eiswerth et al. 2000
8.5	Aesthetic - visual, olfactory	(0-2) Score 2 for both visual and odor problems, 1 either, 0 neither or no mention of these impacts. Surface matting of macrophytes scores 1 for visual impact.	1	Visual impacts: matting at/just below surface.	Smith and Barko 1990; Newroth 1985
9.1	Reduces biodiversity	(0, 1, 3, 5) Score 5 for extensive monospecific stands, 3 for species that become dominant, 1 for small monospecific stands, and 0 if species does not become dominant over other species. Default = 0 for this question if species has been in the trade globally for >30 years and no information is found or if the species is not naturalized outside of its native range.	5	Competitively displaces most other plants, including curlyleaf pondweed.	Aiken et al. 1979; Madsen et al. 1991

Species: <i>Myriophyllum spicatum</i> ; Eurasian watermilfoil					
	Question - USAqWRA	Score and guidance – USAqWRA	Score	Justification	Reference
9.2	Reduces water quality	(0, 1, 3) Score 3 if evidence that this species causes deoxygenation (e.g., through extensive growth in shallow water) or other water quality loss (e.g., loss of water clarity because of high decomposition rates continuously during the growing season), 1 if deoxygenation or other water quality loss is likely based on seasonal growth cycles (e.g., macrophyte that gets to high density and dies off at end of summer), 0 otherwise. Default = 0 for this question if species has been in the trade globally for >30 years and no information is found or if the species is not naturalized outside of its native range.	3	Reduced dissolved oxygen levels, increased nutrient loading, and altered water temperatures.	Madsen 1997; Bates et al. 1985; Dale and Gillespie 1977
9.3	Negatively affect physical processes	(0, 2) Score 2 if species alters hydrology (e.g., increases the chance of flooding) or substrate stability (e.g., increases amount of sediment erosion or deposition), or other physical processes, 0 if the species has no history of modifying physical processes. Default = 0 for this question if species has been in the trade globally for >30 years and no information is found or if the species is not naturalized outside of its native range.	2	Slows flows; increases risk of flooding; increases sedimentation.	Dale and Gillespie 1977
10.1	Human health impairment (e.g. drowning, poisonous, mosquito habitat)	(0-2) Score 1 for one effect, 2 for 2 or more effects.	2	Drowning, mosquito habitat, swimmer's itch.	CAST 2014; Bates et al. 1985; Gallagher and Haller 1990
10.2	Weed of agriculture, including crops, livestock and aquaculture	(0-1) Score 1 if a problem agricultural weed, 0 if no evidence that it is an agricultural weed, or if evidence states that species is in agricultural areas but not problematic.	1	Weed in East Asian rice crops.	Moody 1989; Napompeth and Bay-Peterson 1994
11.1	Management - Ease of management implementation	(0-2) Score 2 if accessibility to weed is difficult, e.g. dense tall impenetrable growths or growing in habitats that are difficult to access by roads or waterways (e.g., swamps). For species that have naturalized outside of their native range, default = 0-2 based upon evidence about habitat and/or growth form if there is no direct evidence from the literature. Default = 0 if species has not naturalized outside of its native range and has been in the trade globally for >30 years.	1	Submersed growth form and interspersed with non-target species may make implementation more difficult due to regulations in the Delta.	

Species: <i>Myriophyllum spicatum</i> ; Eurasian watermilfoil					
	Question - USAqWRA	Score and guidance – USAqWRA	Score	Justification	Reference
11.2	Management - Recognition of management problem	(0-1) Score 1 if difficult to assess weed, e.g., submersed; looks like another species. For species that have naturalized outside of their native range, default to a score between 0-1 based upon growth form evidence if there is no direct evidence from the literature. Default = 0 if species has not naturalized outside of its native range and has been in the trade globally for >30 years.	1	Submersed and may appear similar to native (<i>M. sibiricum</i>) and non-native, invasive (<i>M. aquaticum</i>) congeners, and native coontail (<i>Ceratophyllum demersum</i>).	DiTomaso and Healy 2003; DiTomaso et al. 2013
11.3	Management - Scope of control methods	(0, 1, 2) Score 2 if no control method, 1 if only one control option. If species has naturalized outside of its native range, and there is no direct evidence for either 11.1 or 11.2, do not answer if there is no information. If there is direct evidence for 11.1 and/or 11.2, default to 0 if there is no information for questions 11.3 – 11.6.	0	Multiple herbicides registered with EPA, CDPR; benthic barriers; shading; hand-removal; biocontrol; mechanical; dewatering.	DiTomaso et al. 2013
11.4	Management - Control method suitability	(0-1) Score 1 if control method not always acceptable, e.g., grass carp, unregistered herbicide. If species has naturalized outside of its native range, and there is no direct evidence for either 11.1 or 11.2, do not answer if there is no information.	0	Multiple herbicides registered with EPA, CDPR; benthic barriers; shading; mechanical options; hand-removal are options. Biocontrol not always acceptable.	DiTomaso et al. 2013
11.5	Management - Effectiveness of control	(0, 1, 2) Score 2 if ineffective, 1 if partial control. If species has naturalized outside of its native range, and there is no direct evidence for either 11.1 or 11.2, do not answer if there is no information.	1	Effective chemical control is attainable if appropriate concentrations and exposure times are applied.	Madsen et al. 2015; Madsen et al. 2002; Nault et al. 2014
11.6	Management - Duration of control	(0, 1, 2) Score 2 if no control, 1 if control for 3+ months. If species has naturalized outside of its native range, and there is no direct evidence for either 11.1 or 11.2, do not answer if there is no information.	1	In some systems, control over multiple years is attainable if appropriate concentrations and exposure times are applied.	Madsen et al. 2015; Madsen et al. 2002; Nault et al. 2014
12.1	Problem in other countries	(0, 1, 3, 4, 5) Score 5 if species has been reported to be a widespread problem (i.e., a harmful weed in many other countries), 4 if species has been reported to be a harmful weed in 5 or fewer countries, 3 if species has been reported to be a widespread adventive (but not a harmful weed) in many other countries, 1 if species has been reported to be adventive in 5 or fewer countries, 0 if not adventive elsewhere.	5	United States, Canada, Australia, and ≥ 9 African countries.	CABI 2011; Tomaino 2004
	USAqWRA Score		76		